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ON C_4H VERSUS VIBRATIONALLY EXCITED CO IN IRC +10216

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ABSTRACT

The $N = 12 \rightarrow 11$ doublet of C_4H in IRC +10216 is observed to be nearly symmetric; there is no evidence of a blend with vibrationally excited CO.

Subject headings: infrared: sources — interstellar: molecules — line identifications — radio sources: lines

With advances in receiver sensitivity, the number of molecular radio lines observed in interstellar sources is increasing rapidly, to the point where misidentifications are a definite hazard. A recent example occurs in a source where the density of lines is not especially high: IRC +10216, the well-studied evolved carbon star with a molecular envelope (Morris 1975; McCabe, Smith, and Clegg 1979).

Scoville and Solomon (1978) have recently identified a line at 114,221 MHz in the millimeter-wave spectrum of IRC +10216 as the first rotational transition of vibrationally excited CO. Guélin, Green, and Thaddeus (1978), however, offered an alternative identification which accounted for an otherwise unexplained second line in Scoville and Solomon's spectrum. According to Guélin *et al.*, this pair is a spin doublet, the $N = 12 \rightarrow 11$ rotational transition of the carbon chain radical C_4H. The frequencies are exactly those predicted from lower rotational transitions of C_4H in IRC +10216, but the doublet is expected to be nearly symmetric, while that reported by Scoville and Solomon is apparently asymmetric, the stronger line being the one attributed to CO. The possibility therefore of a fortuitous blend of vibrationally excited CO and C_4H could not be entirely excluded.

To settle this matter we have reobserved C_4H in IRC +10216 with the NRAO 36 foot (11 m) telescope, the same instrument used by Scoville and Solomon. The spectrum we obtained is shown in Figure 1. By chance the interval between successive rotational transitions of C_4H (9515 MHz) is nearly equal to twice the intermediate frequency of the receiver

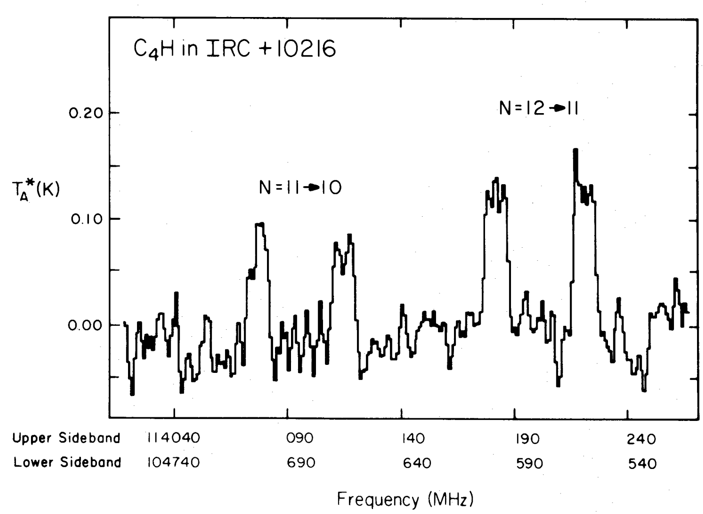

FIG. 1.—Successive spin doublets of C_4H in IRC +10216, $N = 12 \rightarrow 11$ in the upper sideband, $N = 11 \rightarrow 10$ in the lower sideband. The abscissa is rest frequency, calculated on the assumption that the source velocity in the local standard of rest is -26 km s^{-1}. The ordinate is upper sideband antenna temperature, corrected for atmospheric absorption and antenna losses. The absolute calibration of a given sideband is uncertain to at least 20%, but the relative intensities of lines in the same sideband are much more accurate, being determined presumably by receiver noise. The spectral resolution is 1 MHz, and the integration time is 130 minutes.

TABLE 1

LINES OBSERVED IN THE MILLIMETER-WAVE SPECTRUM OF IRC +10216[a]

Molecule	Transition	Rest Frequency (MHz)	Line Width (MHz)	T_A^* (K)[b]
U95579[c]	...	95579	10	0.10 ± 0.01
C_4H	$NJ = 11, 21/2 \rightarrow 10, 19/2$	104667	11	0.08 ± 0.01
C_4H	$NJ = 11, 23/2 \rightarrow 10, 21/2$	104706	10	0.08 ± 0.01
CN	$N = 1 \rightarrow 0$ multiplet	113491[d]	11	1.35 ± 0.09
C_4H	$NJ = 12, 23/2 \rightarrow 11, 21/2$	114182	11	0.12 ± 0.02
C_4H	$NJ = 12, 25/2 \rightarrow 11, 23/2$	114221	11	0.13 ± 0.01
CO	$J = 1 \rightarrow 0$	115271	11	5.48 ± 0.12[e]
U115383[f]	...	115383	11	0.22 ± 0.01

[a] Except for U95.6, the frequencies surveyed are 103.8–107.5 GHz in the lower sideband, 113.3–117.0 GHz in the upper.

[b] Uncertainties are 1 standard deviation of the receiver noise. The actual calibration uncertainties are perhaps 30% of the average intensity, owing to double-sideband operation.

[c] M. Morris and C. Alcock (unpublished).

[d] Frequency of strongest line ($NJF = 1, 3/2, 5/2 \rightarrow 0, 1/2, 3/2$) in the multiplet (Turner and Gammon 1975; Allen and Knapp 1978; Nachman 1979).

[e] From single-sideband measurements, Ulich (1977) gives an intensity for this line of 4.7 K.

[f] Rodriguez Kuiper *et al.* (1977).

(9500 MHz), so two doublets were observed simultaneously, $12 \rightarrow 11$ in the upper sideband, and $11 \rightarrow 10$ in the lower sideband. For the $12 \rightarrow 11$ doublet, our data show two peaks of almost equal intensity and equal width. The intensity averaged over the square top of the low-frequency member of the doublet is 0.125 ± 0.015 K, while that for the high-frequency member is 0.133 ± 0.012 K. The ratio of the averaged peak intensity of the high-frequency to the low-frequency member is 1.06 ± 0.16. The theoretical value for this ratio depends on the sign of the spin-rotation constant γ; for γ positive it is 1.087, and for γ negative it is the inverse of this, 0.920. Our data therefore suggest that γ is probably positive. In any case there is no evidence for the gross asymmetry reported by Scoville and Solomon, and hence no evidence for vibrationally excited CO.

The lower-frequency $11 \rightarrow 10$ doublet in Figure 1 also suggests that γ is positive. There the ratio of averaged intensities of the high-frequency to the low-frequency member is 1.09 ± 0.23 versus 1.10 for γ positive, and 0.91 for γ negative.

Because IRC +10216 is a unique source, with radicals like C_4H which are not observed in Orion A or Sgr B2, we have also surveyed about 10 GHz of the millimeter-wave spectrum to search for new lines. The results, summarized in Table 1, are somewhat disappointing. In the intervals 103.8–107.5 and 113.3–117.0 GHz covered by the double-sideband receiver, we have only definitely detected lines already known: in addition to C_4H these are the fundamental rotational transitions of CN and of CO, and the unidentified line at 115383 MHz first observed by Rodriguez Kuiper *et al.* (1977). At each frequency setting in this survey, the integration time was at least 50 minutes, and the $2\,\sigma$ noise level in the unsmoothed spectra was less than 0.15 K.

In an unsuccessful attempt to find satellite structure which might serve as a clue to the identification of U115383, we obtained a 110 minute spectrum centered

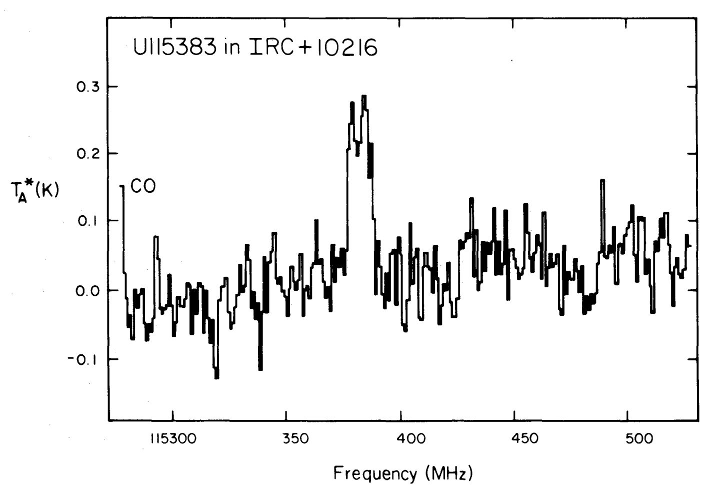

FIG. 2.—Spectrum of U115383 in IRC +10216. Intensity and frequency scales as in Fig. 1.

on this line. As Figure 2 shows, the ramplike shape reported by Rodriguez Kuiper *et al.* is not confirmed; it appears to have instead the characteristic flat top of C_4H and other molecules in IRC +10216.

Also listed in Table 1 is a new unidentified line at 95,579 MHz discovered in IRC +10216 by one of us (M. Morris) and C. Alcock (unpublished). Because the ratio of the frequency of this line to U115383 is very nearly 4.5/5.5, we have attempted to identify both as rotational transitions in a molecule with electronic orbital angular momentum (e.g., C_3H). However, no satisfactory solution along these lines has been found.

In conclusion, we have shown that the line at 114,221 MHz, attributed by Scoville and Solomon to vibrationally excited CO, is probably C_4H, and only C_4H. We have also shown in an arbitrary 10 GHz of the millimeter-wave spectrum of this source that all lines stronger than roughly 0.1 K have already been found.

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